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# THE TITANOTHERIUM BEDS.

By J. B. Hatcher.

In 1857 Meek and Hayden gave the name *Titanotherium* bed to the lowest member of the fresh water, Miocene, lake deposits of the White river, Bad Lands of Dakota and Nebraska.[1] They named these beds from the genus *Titanotherium*, established by Leidy in 1852.[2] This genus embraces the largest, most abundant, and most characteristic vertebrate fossils found in these beds. In 1870 Professor Marsh discovered, in northeastern Colorado, an exposure of these beds, farther south than they had then been reported.[3] He then referred them to "The true Titanotherium beds." In 1877 Professor Marsh proposed the name Brontotherium beds for this same series of strata, from his proposed genus *Brontotherium*.[4] Since there can be no doubt that the *Titanotherium bed* M. and H., and the *Brontotherium beds* Marsh, are identical, and since the former has a priority of at least twenty years, it should be retained.[5] In this paper the plural will be used, as expressing more nearly the true nature of the deposits.

## Geographical Distribution of the Titanotherium Beds.

The Titanotherium beds are known to have a surface exposure in various portions of the western interior plains region. That exposure from which they were first named and described and from which Hayden first made and published a section of them in 1863,[6] is of far greater extent than any other. The Titanotherium beds of this exposure are known to occupy a considerable portion of that country embraced between the Cheyenne, Missouri, and White rivers in S. Dakota, with a western continuation, extending along the eastern and southern slopes of the Black Hills, and westward to near the town of Douglas in Wyoming. While this exposure is seen to have a considerable extent from east to west, yet from north to south it is of very limited extent. This is due to a very slight dip of these beds to the southeast, where they soon pass under the overlying Oreodon and Loup Fork beds. That range of bluffs in southwestern S. Dakota, northwestern Nebraska and central Wyoming, known as Pine Ridge, may be considered as the southern limit of this exposure of the Titanotherium beds. The beds of this region occupy a considerable portion of southwestern S. Dakota, extreme northwestern Nebraska, and a very narrow strip in central and eastern Wyoming. Besides this exposure of the beds, there are other isolated exposures at Long Pine, Nebraska; in northeastern Colorado; in Wyoming, along the Rattlesnake Range, north of the Sweetwater; and Professor Cope has described remains of Titanotheriidæ from Canada.[7]

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[1] Proc. Phila. Acad. Nat. Sci., 1857, p. 120.

[2] Ancient Fauna of Nebr., Leidy, 1852, p. 72.

[3] Am. Jour. Sci., Sept., 1870, p. 292.

[4] Am. Jour. Sci., 3d series, Vol. xiv, p. 354.

[5] Titanotherium, Leidy, 1852, is antedated by Menodus Pomel, 1849 ; but Menodus is essentially preoccupied by Menodon von Meyer, 1838.

[6] Proc. Am. Phil. Soc., 1863, Vol. xii, p. 31.

Although the surface exposures of the Titanotherium beds are of comparatively small extent, yet from the distribution of these exposures the beds are known to extend over a considerable portion of S. Dakota, Nebraska, Colorado, Wyoming, and perhaps portions of Montana and N. Dakota.

## DESCRIPTION OF THE DEPOSITS.

The Titanotherium beds may be briefly characterized as a series of usually light colored, sometimes variegated clays, alternating with less extensive deposits of sandstones and conglomerates, situated at the base of the Miocene and containing among other fossils the remains of Titanotherium and allied forms.

The typical locality from which Meek and Hayden first named the Titanotherium beds and from which the latter first made and published a section of them, is also that locality in the Bad Lands of S. Dakota, which has been more thoroughly explored for vertebrate fossils than any other locality in these beds. It is located in that portion of Washington county embraced between the White and Cheyenne rivers, at that point where they approach nearest to each other. This particular region has not only proved especially rich in vertebrate fossils, but the Titanotherium beds and the entire Miocene series, up to the Loup Fork, has attained a development here unsurpassed, if not unequaled, elsewhere. In no other region has erosion done more to aid the investigator than here; whether his aim be to study the country from a purely geological standpoint, to collect material for the paleontological laboratory, or to study the laws and observe the rate and effects of erosion, under the many and varied circumstances which this region presents. Since the materials composing the Titanotherium beds are very similar throughout the entire distribution of the beds, a description of the deposits at the typical locality may be considered as representing fairly well the character of the deposits at any other locality.

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[7] Contributions to Can. Pal., Vol. iii, p. 8.

The section published by Hayden in 1863 agrees in all important points with those published since by other authorities. As stated by Hayden, the beds vary in thickness at different localities. At no locality has he given a thickness of more than 100 feet. The writer has found, by actual measurement, that they attain a thickness in some places at least, of 180 feet. As stated before, they are composed of clays, sandstones, and conglomerates. The clays greatly predominate, consist of very fine particles, and are quite compact. In places they are composed almost entirely of pure kaolin, but they often contain a considerable portion of sand. Near the bottom of the beds the color is often red or variegated, due to the presence in them of small quantities of red oxide of iron; but the prevailing color is a very characteristic and delicate greenish white. The clays usually contain little or no cementing substance, and are held together almost entirely by adhesion. Occasionally, however, there are quite persistent layers of clay nodules, or concretions in which the clays are firmly cemented by carbonate of lime. Owing to the extreme minuteness of the particles forming the clays and the absence of sufficient cementing material in them, in most places they readily yield to the action of water and are quite rapidly eroded. The clays of the Titanotherium beds were probably derived from two sources, viz., from the Cretaceous clays and shales, and from the kaolinization of granitic feldspars.

The sandstones are never entirely continuous, and never more than a few feet thick. They present every degree of compactness, from loose beds of sand to the most solid sandstones. They are composed of quartz, feldspar and mica, and are evidently of granitic origin. When solidified the cementing substance is carbonate of lime.

The conglomerates, like the sandstones, are not constant, are of very limited vertical extent, never more than a few feet thick. They are usually quite hard, being firmly held together by carbonate of lime. A section of the beds taken at any point and showing the relative position and thickness of the sandstones, clays, and conglomerates is of little value, since these vary much at different and quite adjacent localities.

The varying hardness of the different strata of the Titanotherium and overlying later Miocene beds, by offering unlike degrees of resistance to erosion, have succeeded in producing in this particular region an exhibition of characteristic Bad Lands scenery, unsurpassed elsewhere in the Miocene. The surface of the country in this region is scarred by numerous deeply eroded canyons. The intervening ridges are rugged and barren, often terminating for miles in sharp, serrated crests. The walls of these canyons present a series of terraces or projecting ledges from top to bottom, due to different degrees of hardness in the different strata. Sometimes these ledges are but a few feet wide, or just wide enough to allow a person on foot to pass along on them. At other times when the harder layers of which they are composed are of greater thickness, they may be several hundred feet wide, and their surface strewn with the fossil bones of Titanotherium, Elotherium, Hyracodon, Hyænodon, Oreodon, turtles, etc., washed out of the overlying beds, by the slow process of denudation, presents a remarkable, not to say, sepulchral appearance.

Toward the interior of the Bad Lands, midway between the White and Cheyenne rivers, side branches of the main canyons have cut their way entirely through the dividing ridges and have produced particularly picturesque effects. Characteristic among these are the Devil's Tower, at the south end of Sheep Mountain, in the eastern portion of the Bad Lands; Chimney Rock, near their center, and the Tabled Rocks along their western border.

The location of such especially characteristic Bad Land scenery, in this particular region, is doubtless due to the near approach of the White and Cheyenne rivers to each other at this place. Since the Miocene deposits of this region are essentially horizontal, and form the summit of the divide between these two streams; this divide would be of essentially the same altitude, in reference to the beds of these streams, whether the latter were *near together* or *far removed* from each other. Therefore these streams upon approaching nearer to each other, as they do in this region, where they are only about 20 miles apart, would greatly reduce the length of their respective, intervening tributaries, without decreasing the height of the divide which separates them. This would necessarily increase the average rate of fall of the tributaries, and correspondingly the rapidity of the flow of their waters, and therefore the erosive power of the latter.

In various portions of the Titanotherium beds there are numerous vertical veins of chalcedony running through the beds in every direction. These veins vary in thickness from that of a sheet of paper to about two inches. On first thought the writer was inclined to attribute their origin to mud cracks, any particular region where they now occur having been for short periods, during seasons of low water, above the water level and subjected to the action of the atmosphere and the heat of the sun became baked and cracked; just as we now so often see at low water along the mud flats of our streams and lakes. But it is obvious that if these veins owe their origin to mud cracks they would be filled, not with chalcedony, but with the same materials as the overlying beds; for when the waters again covered this region, the mud cracks would be immediately filled by sedimentation and with the same materials that now compose the overlying beds. It has since occurred to the writer, that these cracks were not made while the particular strata in which they now appear occupied the immediate bottom of the lake, but after the overlying beds were deposited. The extreme fineness of the particles forming the clays of the Titanotherium beds in those places where these veins occur is evidence that the clays were deposited by a slow process of sedimentation in still waters. The bottom of a lake where such materials were being laid down would consist for several feet of a very thin mud or ooze. This would gradually become firmer toward the bottom as deposition continued, but would still mechanically retain a considerable per cent. of water. Later, when the entire overlying series of strata were deposited and the region brought permanently above the water level this imprisoned water would gradually disappear, by filtration or otherwise, aided perhaps by the pressure of the superincumbent beds. This loss of moisture in the clays would diminish their volume and bring about a readjustment of the particles composing them. The decrease in volume would be taken up in two ways: First, as in the case of mud cracks, the particles would tend to collect about certain centers in the beds, and these centers of adhesion would increase laterally by the attraction of adjacent particles until cracks of varying thickness would form between the peripherys of adjacent centers of adhesion. The pressure of the overlying beds would determine the vertical direction of these cracks, and would also afford the means for the second way, by which the decrease in the volume of the clays would be taken up, viz., by a decrease in the vertical thickness of the beds. These cracks, thus formed far beneath the surface, were afterward filled by chalcedony dissolved out of the overlying beds by heated waters percolating through them. Occasionally other minerals, as ordinary calcite and its less common variety known as Iceland spar, are found in small cavities in these veins. Localities containing these peculiar veins of chalcedony resemble both in appearance and structure a huge septaria, except that the veins in the former are much smaller in comparison with the area of the intervening spaces than in septariæ. A singular fact in connection with the position of areas exhibiting this peculiar structure is also thought to afford in itself evidence in favor of this view of the origin of the veins. These veins occur only in certain localities of limited area. Any single locality is never more than a few square miles in extent. These small and isolated areas, wherever it has been possible to determine their relation to the underlying beds, have been found to have been deposited in an eroded valley or depression of the latter. Such depressions would afford a natural basin for the waters, held mechanically by the clays, and would prevent a rapid drainage during their deposition.

## STRATIGRAPHICAL POSITION OF THE TITANOTHERIUM BEDS.

### THE UNDERLYING BEDS.

The Titanotherium beds are underlaid by various older formations, from the Laramie to early Paleozoic or perhaps Archean. In most places they rest unconformably upon the eroded surface of some member of the Cretaceous, most frequently the Fort Pierre shales. At the mouth of Beaver creek, a tributary of White river, near the Nebraska and Dakota State line, the writer in 1886 observed the Titanotherium beds resting upon the eroded surface of the chalk of Cretaceous No. 3, so well developed in central and western Kansas. This is believed to be a more northwestern extension of these beds than had then been reported.

### THE TITANOTHERIUM BEDS.

The Titanotherium beds may be divided into Lower, Middle, and Upper beds, each characterized by different forms of the Titanotheriidæ. Accepting a total thickness of 180 feet as the maximum thickness of these beds, 50 feet of this would belong to the Lower, 100 feet to the Middle, and 30 feet to the Upper beds. The different forms of Titanotheriidæ, especially characteristic of these three divisions will be pointed out and figured later in this article.

## THE OVERLYING BEDS.

The Titanotherium beds are everywhere overlaid by the Oreodon beds, except where the latter have been removed by erosion. So far as noticed there are in the Bad Lands of S. Dakota no evidence of any unconformity between the Oreodon and Titanotherium beds, unless the sudden change from one fauna to another should be regarded as evidence of an unconformity or at least as indicating a considerable break in sedimentation between the two beds.

Southwest of the Dakota Bad Lands in the extreme northwestern portion of Nebraska there seems to be some evidence of an unconformity between the Titanotherium and Oreodon beds, or at least that for a considerable period immediately following the deposition of the Titanotherium beds, this region became dry land and that the Oreodon beds were subsequently laid down upon the eroded surface of the Titanotherium beds. At the extreme head of Cottonwood creek, a small tributary of White river, from the northwest, in the northwestern part of Dawes county, there is an isolated butte composed entirely of the Titanotherium beds and containing many Titanotherium bones. The different strata composing this butte are horizontal. About one mile south of this isolated butte is a range of bluffs of the characteristic Oreodon beds, containing numerous bones of Oreodon and other associated animals.

In the first mentioned butte Titanotherium bones are found at the same altitude at which Oreodon bones occur in the bluffs to the south. Whether this occurrence of Titanotherium and Oreodon bones at the same altitude in quite adjacent beds is due to the Oreodon beds having been deposited upon the eroded surface of the Titanotherium beds, or to differences in the level of the bottom of the lake, at the beginning of the Miocene period, could not be determined. The horizontal position of the strata composing the Titanotherium butte would seem to favor the first conclusion, since if these strata had been laid down upon a sloping bottom they would, in their lower members at least, partake of the inclination of the bottom of the lake.

About six miles northeast of the town of Chadron, in Dawes county, Nebraska, on a small branch of the west fork of Dry creek, the writer, in 1886, while collecting missing portions of the skeleton of Professor Marsh's type of *Titanotherium* (*Brontops*) *robustum*, discovered by H. C. Clifford in 1875, observed several feet above the horizon in which this remarkably complete skeleton was found, and certainly not far from the top of the Titanotherium beds, positive evidence of a break in sedimentation at this place at least. This evidence consists in the occurrence at this place of a very dark colored layer of vegetable mould about two feet thick, accumulated no doubt during a period of elevation above water level.

Owing to the fact that the Titanotherium and Oreodon beds of S. Dakota and Nebraska are approximately horizontal, it is almost impossible to determine there, just what their stratigraphic relations are. Farther west, near the head of Lance and Harney creeks, in Wyoming, the Titanotherium beds, at least, dip to the southward at a considerable angle. The writer has been unable to make any but the most superficial observations in this region, which, if carefully examined, would doubtless furnish a solution of the actual stratigraphic relations of these beds.

Professor W. P. Jenney, of the U. S. Geol. Survey, has reported to the writer an account of the discovery of a small Miocene lake in the Black Hills. As a description of this singular and interesting deposit a portion of Professor Jenney's letter is quoted. He says: "About 1879–'80 I was informed that fossil bones . . . . had been found in a prospecting shaft near Lead City. I visited the locality and obtained possession of three nearly perfect skulls . . . . These fossils I sent to Professor Marsh at New Haven, accompanied by a letter giving a sketch and full description of the occurrence, and received a reply stating that they were all *Oreodon culbertsonii* (this specific name is from memory but I think correct).

"This Miocene deposit is situated about half a mile southeasterly from Lead City, South Dakota, and nearly five miles south of the city of Deadwood, at an elevation of about 5,200 feet above the ocean. . . . . Of the extent of this tertiary deposit very little is known. It does not outcrop at the surface and appears to occupy a small, deep channel or basin eroded in the Archæan slates which outcrop on all sides within a radius of 1000 to 3000 feet. . . . . This occurrence is peculiar not only in forming an outlier to the great Miocene deposits and in occupying a basin eroded in a range of steep Archæan hills where lakes are now unknown, but also in the nature of the deposit itself, which so closely resembles, in appearance at least, the deposits of the same age on the plains. The clays of the latter were probably derived from Cretaceous shales, but the sediments filling this lake would naturally be expected to be very different, the rocks in the vicinity being Archæan slates capped by Potsdam sandstone and shales, and locally overlaid by masses of eruptive post-Cretaceous porphyry. . . . ."

That this small lake was, during Miocene times, entirely isolated from the great body of water to the eastward can hardly be questioned. The similarity just referred to by Professor Jenney as existing between the deposits of the small lake and those of the larger one is probably due to the materials composing both having been derived largely from a common source. The prevalence everywhere throughout the Miocene of large quantities of sands and conglomerates, composed of coarse grains or pebbles of quartz, feldspars, and mica, is sufficient evidence that the materials composing the beds of the Miocene were derived largely from sources other than the Cretaceous shales, which contain little sand and are always very fine grained. The coarser sands and conglomerates were doubtless derived from Jurassic, Paleozoic, and Archean rocks, and a considerable portion of the Miocene clays probably owe their origin to the decomposition of the slates of these older formations and the kaolinization of granitic feldspars.

## DIVISION OF THE TITANOTHERIUM BEDS INTO LOWER, MIDDLE AND UPPER BEDS.

During the seasons of 1886, 1887, and 1888, the writer spent fifteen months in the White River Miocene beds of S. Dakota and Nebraska, collecting material for Professor Marsh's Monograph on the *Titanotheridæ* (*Brontotheriidæ*). Among the material collected was 105 nearly complete Titanotherium skulls, and many portions of skeletons and disarticulated bones; besides the remains of many other associated animals. Early in the season of 1886 it became apparent that certain forms of skulls were characteristic of certain horizons in the beds. This fact showed the importance of keeping, so far as possible, an exact record of the horizon from which each skull or skeleton was taken. From actual measurement the vertical range of the Titanotheriidæ was found to be about 180 feet. For convenience in keeping a record of horizons the beds were divided into three divisions of 60 feet each, and each of these three divisions was subdivided into three divisions of 20 feet each. The different skulls and skeletons, when dug out, were each given a separate letter or number, and this letter or number was placed in that subdivision of the beds from which the skull or skeleton was taken.

At present about 60 of these skulls and several more or less complete skeletons have been freed from their matrix. When studied in connection with the horizons from which they were taken, these remains show that a regular and systematic development took place in these animals from the base to the top of the beds. The most noticeable change which took place in the Titanotheriidæ was a gradual and decided increase in their size from the lowest to the uppermost beds, as is shown by the increase in the size of the skulls, fore and hind limbs, and other portions of the skeleton. Individuals found near the bottom of the beds are little, if any, larger than the living rhinoceros. From this they gradually increase in size as we go up until at the top we find a type described by Professor Marsh as Titanops, rivaling the modern elephant in size.

This increase in size from the base to the summit of the beds was attended by a very marked development in certain portions of the skeleton, noticeable among which are the following: A variation in shape and an increase in the size and length of the horncores as compared with the size of the skulls, attended, near the summit of the beds at least, by a decided shortening of the nasals.

There were also changes taking place in the dentition of these animals, especially in the number of incisors and in the structure of the last, upper, true molar. The number of incisors, though probably never constant, even in the same species, shows a tendency to decrease in skulls found near the summit of the beds. At the base of the beds the number of incisors is from one to three on a side, while at the top there are never more than two on a side, often only one, sometimes none. In skulls from the very lowest beds the incisors have already become so rudimentary as to be no longer functional. As would be expected, the number of incisors decreased after they became of no functional value. In the matter of incisors the Titanotheriidæ were, at the time of their extermination, in a fair way to accomplish just what the somewhat related but more persistent Rhinocerotidæ have very nearly succeeded in doing, viz., the elimination of the incisor dentition. The number of incisors in the Titanotheriidæ varies with age in the same individual. These teeth were but loosely set in the comparatively thin alveolar border between the canines, and showed a decided tendency to drop out in old age, their alveoles afterward becoming entirely closed. This is well shown in several instances where on one side of a jaw there may be 1, 2, or 3 incisors, while on the other side of the same jaw there will be 0, 1, or 2 and no alveole for the missing tooth. The number of incisors can hardly be considered as of either generic or specific importance in the Titanotheridæ where they are no longer functional and vary with individuals in the same species and with age in the same individual. The same may be said of the presence or absence of the first premolar.

In the structure of the last upper true molar we find a change taking place in the development of a posterior, inner cone. Individuals from the base of the beds show scarcely any indications of this cone, but as we proceed upward in the beds, there is a marked increase in the development of the inner basal ridge on the inner posterior angle of the last upper true molar. This development frequently succeeds near the middle of the beds in producing a perfect posterior inner cone.

Other variations are noticeable in the dentition and in the character of the nasals, but they are common to individuals from any horizon whatsoever, and are thought to be of sexual importance only. Among variations of this nature may be mentioned the following: Differences in the size of the canines as compared with the molars and premolars; presence, absence, or want of continuity of an inner basal ridge on the superior premolars; comparative strength and rugosity of the nasals. Since slender and delicate nasals, small canines and upper premolars with only a very slight or no basal ridge on the inner border, are associated in the same skulls; these skulls are considered to have belonged to females, while those skulls in the same horizons, with stronger and more rugose nasals, larger canines and a well developed inner basal ridge on the upper premolars represent their male companions.

There were also changes taking place in other portions of the skeletons of these animals, important among which may be mentioned the development of a third trochanter. Femora from the bottom of the beds were quite small and with only a rudimentary third trochanter. Toward the middle of the beds they increase in size and show a well marked third trochanter, while at the top of the beds this process has become quite well developed and is of moderate size.

The most important change that took place in the Titanotheriidæ, and the only one perhaps of generic importance, is to be found in the fore foot. Early in the season of 1886 the writer discovered near the base of the Titanotherium beds a portion of the skeleton of a very small individual with both fore feet and limbs in position. The carpus of this individual was found to possess an additional bone (*the trapezium*) hitherto unknown in the Titanotheriidæ. This fortunate discovery of a skeleton, at the base of the deposits, with a distinct trapezium showing a perfect articulation with the trapezoid, may be found to be of considerable importance as establishing a closer relation of Titanotherium to Diplacodon from the upper Eocene than has yet been pointed out, especially if this latter form should prove to possess a trapezium, as it is now almost certain it did. The trapezium, though present in the earliest forms of the Titanotheridæ, was quite small and soon disappeared entirely, leaving no vestige of a first digit. Among many more or less complete fore feet found in the upper part of the Lower, in the Middle, and Upper beds, no trapezium has yet been found, while several have been found at the base of the beds.

It is quite probable that those forms of Titanotheriidæ with three incisors described by Professor Marsh under the generic name of *Teleodus* will be found to possess a trapezium.[8] If such should prove to be the case, the genus *Teleodus*, Marsh can then be considered as distinguished from that of *Titanotherium*, Leidy by a definite and constant character, viz., the presence of a trapezium. Individuals with three incisors collected by the writer have invariably been found at the bottom of the beds and the small size of other individuals with three incisors, discovered by other collectors, indicate that they also were taken from the same horizon. There would appear, therefore, to be little doubt that the presence of a trapezium and three incisors are associated in the same individuals. That the latter character was not constant is shown by the presence of three incisors on one side and two on the other in the same jaw, with no alveole for the missing tooth.

Variations occur also in the number of sacral vertebræ. But since these are clearly dependent upon the age of the individual they are not considered here. All fully adult specimens show four sacrals, younger ones only two or three.

In figure 3 the side view of a skull from the base of the Titanotherium beds is represented, showing the small round horncores and long nasals which are characteristic of skulls from this horizon. In figure 2 the side view of a skull from the Middle beds is represented, showing horncores and nasals of medium length. Figure 1 represents the side view of a

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[8] Am. Jour. Sci , June, 1890, p. 524.

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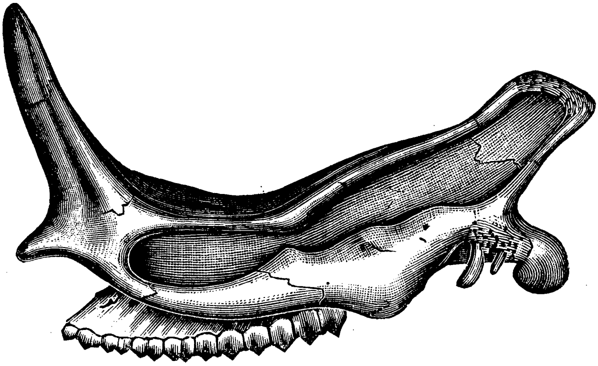
| Oreodon Beds. | | Reddish brown clays, with occasional concretionary layers, Remains of Oreodon, Hyracodon, Hyænodon, Elotherium, etc. About 500 feet thick. |
| TITANOTHERIUM BEDS, 180 FEET THICK. | Upper Beds, 30 ft. | Characterized by Titanotheriidæ of large size. Horns 10–18 in. long, elliptical to sub-ovate in cross-section. Nasals very short and pointed. Incisors never more than 2. Internal cingulum on upper premolars not strongly marked in either sex. Posterior inner cone on last upper molar. Third trochanter present. Trapezium absent. General form of skull shown in fig. 1. |
| | Middle Beds, 100 ft. | Characterized by Titanotheriidæ ot medium size. Horns 4–10 in. long, circular to sub-triangular in cross-section. Nasals of moderate length, with broad or pointed extremities. Incisors never more than 2. *Strong* internal cingulum on upper premolars of males only. Posterior inner cone on last upper molar. Third trochanter present. Trapezium absent. General form of skull represented in fig. 2. |
| | Lower Beds, 50 ft. | Characterized by Titanotheriidæ of small size. Horns rudimentary or from 1–4 in. long, circular in cross-section. Nasals long and pointed. Incisors occasionally as many as 3. *Strong* internal cingulum on upper premolars in males only. No posterior inner cone on last upper molar. Third trochanter somewhat rudimentary. Trapezium present in earliest forms. General form of skull shown in fig. 3. |
| Underlying Beds. | | Represented by various formations from Laramie to Archean. |

Section of Titanotherium Beds showing relative thickness of Upper, Middle, and Lower Beds, with brief descriptions of forms of Titanotheriidæ common to each.

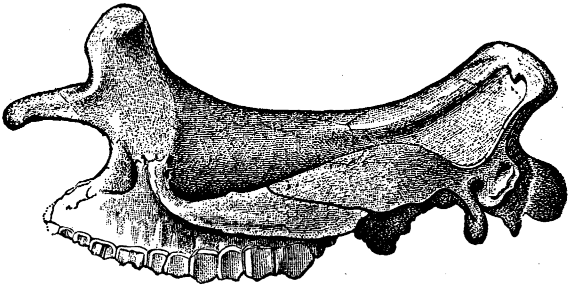
skull from the Upper beds with the characteristic long horn-cores and short nasals. The nasals are not so short in this

FIG. 1.



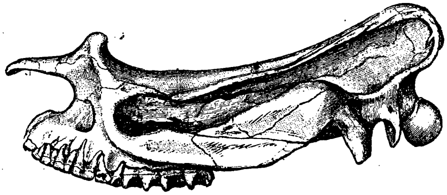
*Titanotherium acre*, $\frac{1}{12}$. Cope.

FIG. 2.



*Titanotherium ingens* Marsh; $\frac{1}{12}$ (After Marsh).

FIG. 3.



*Titanotherium heloceras* Cope; $\frac{1}{12}$ (After Marsh).

skull as in many others. The figures are drawn to the same scale, one-twelfth natural size, and represent well the increase in the size of the skulls from the base to the summit of the beds. They are arranged on the opposite page in the order in which they occur in the beds commencing at the top.

Intermediate forms in the middle of the beds have a much greater vertical range than their smaller ancestors in the underlying beds or their larger survivors in the overlying beds.

Between the skulls here figured there are many intermediate forms, showing every stage of development from a very small skull found at the very bottom of the beds, which measures only 22 inches from occipital condyles to the extremity of nasals, with very rudimentary horncores only 1⅛ inches high to forms similar to that represented at the top, which measure more than 36 inches from occipital condyles to extremity of nasals, with horncores over a foot long and having an expanse of two feet or more.[9]

In the section of the Titanotherium beds accompanying this paper the relative thickness of the Lower, Middle, and Upper beds are shown, with brief descriptions of forms of Titanotheridæ characteristic of each.

Much additional information bearing upon the development which took place in the Titanotheriidæ will doubtless be brought to light, when the large collections either made or purchased by the writer for use in the preparation of Professor Marsh's monograph and now numbering nearly 200 complete skulls and many more or less complete skeletons shall have been worked up. It is safe to say that there is scarcely a single foot of sediment within the entire vertical range of the Titanotheridæ that is not represented by material in this collection. Only those facts bearing upon the evolution of the Titanotheriidæ which have presented themselves to the writer in connection with his field work are set forth in this paper. It is to be hoped that the few results here recorded may suggest to other collectors the importance of keeping, as nearly as possible, accurate data of horizons; since a familiarity with the different horizons as characterized by different and closely related forms is clearly indispensible in making an intelligent classification of any group of fossils, more especially when they are as highly specialized and as susceptible to the influence of constantly changing environments as were the Titanotheriidæ.

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[9] These facts were communicated by the writer to Professor Marsh in 1886, and were referred to by the latter in the Am. Jour. Sci., Feb., 1889, p. 163, and the Ninth Ann. Report U. S. Geol. S., p. 114.

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